MODULAR REGULATOR

Cross-Reference to Related Application

This application is a §111(a) application relating to commonly owned co-pending U.S. Provisional Application Serial No. 60/443,275, entitled "Modular Regulator," filed January 28, 2003.

Field of the Invention

The present invention relates to regulators and, more particularly, to a new and improved regulator for use in controlling and modulating the pressure of supplied gases.

Background of the Invention

Gas regulators are a staple of industry, being used to control and maintain the pressure of gases for a wide variety of industrial, commercial and residential applications. Gas regulators are typically precision devices, which are able to maintain relatively constant output pressures over a wide range of input pressures. One problem with many existing pressure regulators is that they are designed to provide only one predetermined output pressure. Consequently, if a user requires a wide range of output pressures, then he or she must purchase and stock different pressure regulators. This can become very expensive for the user. Moreover, manufacturers of existing pressure regulators must produce and stock several different regulators and components thereof, resulting in increased costs of production and inventory.

Another concern with existing regulators is that when a regulator is in need of maintenance or replacement, it can represent a sizeable cost in both time and labor.

For instance, maintenance of a regulator or replacement of components thereof typically requires disassembling many or all of the components of the regulator. In addition, maintenance and replacement of existing regulators typically require disconnecting them and their often-associated equipment, such as flow meters, valves and the like, from a gas supply to which they are attached. Experience has also shown that, because of the delicate nature of the regulator and the interplay between its components, inattention or carelessness during maintenance, as well as the removal and installation processes themselves, may result in damage or misadjustment to the regulator. Therefore, any minimization of disassembly of the regulator components and elimination of the need to remove the regulator from the gas system during maintenance or replacement would greatly reduce time and labor costs. At the same time, the chance of any damage to or misadjustment of the regulator would be diminished.

Finally, a major objective in designing a regulator is to protect the regulator's internal components from harmful conditions while the regulator is in use. For instance, a regulator is often subject to pressures that exceed the regulator's normal operating specification. Many existing regulators are designed to only handle pressures that slightly exceed the regulator's normal operating specification, but lack sufficient safety mechanisms to relieve pressures that grossly exceed the regulator's normal operating specification. Without an appropriate safety relief mechanism, the regulator or the gas system to which the regulator is attached is likely to be damaged.

Another example of a harmful condition is the introduction of foreign matter within the regulator itself. Dust, debris and other small particles can affect the performance of

the regulator or, in some cases, damage the regulator. Accordingly, protection of the internal components of a regulator is paramount.

Various pressure regulators have been proposed in the past for addressing the aforesaid concerns. For instance, U.S. Patent No. 4,966,183 to Williamson (the "Williamson '183 Patent") discloses a gas pressure regulator that contains a relief valve for relieving pressures greater than the desired output pressure. The Williamson '183 Patent discloses that the relief valve can be adjusted manually or electrically. However, manual or electrical adjustment is not always reliable, such that manual adjustment invites room for human error, while electrical adjustment would fail in the event of power outages. As a result, the desired output pressure of the regulator may not always be achieved.

The Williamson '183 Patent also discloses the use of a filter to prevent foreign matter from passing through a bleed orifice within a diaphragm assembly. However, the filter's location does not prevent foreign matter from substantially traveling through the regulator that could affect other pressure regulation elements of the regulator. As a result, the accumulation of foreign matter could buildup in areas of the regulator other than the bleed orifice. As a result, the desired output pressure of the regulator can be affected or the regulator could be damaged.

In addition, the Williamson '183 Patent does not disclose that the regulator can remain attached to the gas system while being repaired. As a result, removal of the entire regulator from the gas system for repair or replacement would involve additional cost in time and labor.

U.S. Patent No. 5,279,327 to Alsobrooks (the "Alsobrooks '327 Patent") discloses a fluid pressure regulator that includes a valve insert that sets the flow capacity of the regulator. However, the Alsobrooks '327 Patent does not disclose whether the regulator can accommodate valve inserts that allow for the provision of different flow capacities. Accordingly, different pressure regulators must be purchased and stocked in inventory if different flow capacities are desired.

U.S. Patent No. 6,298,828 to Concialdi (the "Concialdi '828 Patent") discloses a fuel pressure regulator that includes a replaceable fuel return orifice element mounted within the regulator housing. The Concialdi '828 Patent discloses that by replacing the element, the orifice contained therein can be sized to adjust the fuel pressure. However, the Concialdi '828 Patent discloses that replacement of the orifice element requires a complete disassembly of the regulator housing. As a result, additional labor costs would be incurred.

U.S. Patent No. 6,276,392 to Hendrickson (the "Hendrickson '392 Patent") discloses a liquid pressure regulator for use with water distribution systems. The Hendrickson '392 Patent discloses the use of a replaceable spring that corresponds to a desired outlet pressure. However, the Hendrickson '392 Patent does not disclose means for the safe release of fluid pressure greater than that of the capacity of the regulator.

Finally, none of the regulators covered by the aforementioned patents contain an appropriate safety mechanism that enable them to relieve pressures that grossly exceed their respective normal operating specifications.

Summary of the Invention

The present invention improves upon gas pressure regulators as described in the prior art. The most prominent feature of the regulator is that it provides a user with the flexibility to change the capacity of the gas system to which the regulator is attached. In this regard, the regulator accommodates interchangeable modules that are rated for different flow capacities. Each module has a stem whose diameter is rated for a specific flow capacity. For example, if a user has a module rated for a maximum of 10 scfm, and wishes to increase the capacity of the gas system to 15 scfm, the user can simply replace the 10 scfm module with a 15 scfm module. As a result, the regulator has an advantage in that the user need only purchase and stock one regulator and different modules and, thus, the user's costs are reduced. Similarly, a manufacturer and distributor need only stock components for one regulator and several different stem sizes, rather than stocking components for several different regulators.

In addition, the regulator includes a base that provides an interface between the regulator's module and the system to which the regulator is attached. Thus, if maintenance or replacement of a module is necessary, all a user must do is remove the module without having to disconnect the entire regulator and its often-associated components, such as gauges and couplings, from the gas system. This reduces both time and labor costs when maintenance or replacement is carried out.

The regulator also features a centrally located body plug within a regulator body, which allows for the replacement of a filter, which prevents foreign objects from entering the regulator. This eliminates the need to substantially disassemble the regulator components when replacing the filter. Along these lines, the filter is located in a position

that greatly reduces the amount of foreign matter from entering into the regulator. This helps prevent inefficiencies of or damage to the regulator.

The regulator also includes a diaphragm assembly that allows for the relief of pressures that exceed the regulator's normal operating specification, as well as safety components that allow for the release of pressures that grossly exceed that of the regulator's normal operating specification. Accordingly, the safety mechanism prevents or reduces damage to the regulator's components and to the gas system to which the regulator is attached.

Specifically, the present invention has been adapted for use in the supply of carbon dioxide gas for carbonated beverage dispensing. However, the present invention can be utilized in other scenarios, environments and conditions.

Further features and advantages of the invention will appear more clearly on a reading of the detailed description of a preferred embodiment of the invention, which is given below by way of example only with reference to the accompanying drawings.

Brief Description of the Drawings

For a better understanding of the present invention, reference is made to the following detailed description of an exemplary embodiment considered in conjunction with the accompanying drawings, in which:

FIG. 1 is a top perspective view of a regulator constructed in accordance with an exemplary embodiment of the present invention.

FIG. 2 is a cross-sectional view, taken along section line II-II and looking in the direction of the arrows, of the regulator shown in **FIG. 1**.

FIG. 3a is a top plan view of a base employed by the regulator shown in **FIGS. 1** and **2.**

FIG. 3b is a cross-sectional view, taken along section line IIIb-IIIb and looking in the direction of the arrows, of the base shown in **FIG. 3a**.

FIG. 3c is a cross-sectional view, taken along section line IIIc-IIIc and looking in the direction of the arrows, of the base shown in **FIG. 3a**.

FIG. 4a is a top plan view of a body employed by the regulator shown in **FIGS. 1** and **2**.

FIG. 4b is a cross-sectional view, taken along section line IVb-IVb and looking in the direction of the arrows, of the body shown in **FIG. 4a.**

FIG. 4c is a cross-sectional view, taken along section line IVc-IVc and looking in the direction of the arrows, of the body shown in **FIG. 4a.**

FIG. 5 is an exploded perspective view of pressure regulation elements of the regulator shown in **FIG. 2.**

FIGS. 6a and **6b** are exploded perspective views of a pair of safety elements of the regulator shown in **FIG. 2**.

FIG. 7 is an exploded perspective view of the regulator of **FIG. 1** shown attached to a gas system and to a mounting bracket.

Detailed Description of the Drawings

Referring to **FIGS. 1** and **2**, a modular regulator **10** includes a cylindrical-shaped base **12**, a cylindrical-shaped body **14** (see **FIG. 2**) and a bonnet **16**. The base **12**, whose features and function will be described in greater detail hereinafter, provides an

interface between pressure regulation components **18** (not shown in **FIG. 1**, but see **FIGS. 2** and **5**) of the regulator **10** and a gas system to which the regulator **10** is connected. The base **12** is preferably manufactured from zinc #3 ingot, but it may be manufactured from other materials. The body **14,** whose features and function shall be described in greater detail hereinafter, houses and supports the pressure regulation components **18** and safety components **20** (not shown in **FIG. 1**, but see **FIGS. 2** and **6**) of the regulator **10.** The body **14** is preferably manufactured from aluminum bar alloy 2011-T3, but it may be manufactured from other materials. The bonnet **16**, whose features and function will be described in greater detail hereinafter, covers and houses certain components of the pressure regulation components **18**. The bonnet **16** is preferably manufactured from ZAMAK 3 zinc alloy, but it may be manufactured from other materials. Each individual component of the pressure regulation components **18** as well as the safety components **20** and its function shall be described hereinafter.

Referring to **FIGS. 1, 2** and **3a** through **3c**, the base **12** includes a pair of ends **22**, **24** and a cylindrical-shaped aperture **26** that extends longitudinally through the base **12** from the end **22** to the end **24**. The aperture **26** is sized and dimensioned to accommodate the receipt and installation of the body **14** in the base **12**. The base **12** further includes a base wall **28** having an inner surface **30** and an outer surface **32**. The inner surface **30** of the base wall **28** surrounds the aperture **26**, thereby forming a socket for the body **14**. The base wall **28** is stepped proximate to the end **24** of the base **12**, thereby forming an annular seat **34** whose function will be described hereinafter.

Still referring to **FIGS. 1, 2** and **3a** through **3c**, the base **12** further includes a pair of diametrically opposed inlets **36, 38**, each of which extends laterally through the base wall **28** from its outer surface **32** to its inner surface **30** and which terminates at the aperture **26**. The base **12** further includes a pair of diametrically opposed outlets **40, 42**, each of which extends laterally through the base wall **28** from its outer surface **32** to its inner surface **30** and which terminates at the aperture **26**. The inlets **36, 38** are oriented perpendicularly relative to the outlets **40, 42** and on a common lateral plane that is intermediate the ends **22, 24** of the base **12**. The outlets **40, 42** are also oriented on a common lateral plane, but one which is proximate the end **22** of the base **12**. Each of the inlets **36, 38** and each of the outlets **40, 42** are internally threaded. Alternatively, the inlets **36, 38** and/or the outlets **40, 42** need not be threaded. The function of the inlets **36, 38** and the outlets **40, 42** will be described hereinafter.

Still referring to **FIGS. 1, 2** and **3a** through **3c,** the base **12** further includes cavities **44, 46, 48, 50**, each of which extends laterally through the base wall **28** from its outer surface **32** to its inner surface **30** and which terminates at the aperture **26.** More particularly, the cavity **44** is located proximate the inlet **36**, while the cavity **46** is located proximate the inlet **38**. Similarly, the cavity **48** is located proximate the outlet **40**, while the cavity **50** is located proximate the outlet **42**. The cavities **44, 46, 48, 50** are oriented on a common lateral plane that is proximate to the end **24** of the base **12**. The function of the cavities **44, 46, 48, 50** shall be described hereinafter. Preferably, the base **12** includes the four cavities **44, 46, 48, 50**, but it may include a greater or lesser number than four. A bottom surface **52** of the base **12** includes a pair of mounting holes **54, 56**

for receipt of a mounting bracket **58** (not shown in **FIGS. 1, 2** and **3a** through **3c**, but see **FIG. 7**) whose features and function will be described hereinafter.

Referring now to **FIGS. 2** and **4a** through **4c**, the body **14** includes a pair of ends **60**, **62** and a pair of peripheral grooves **64, 66**, each of which encircles the body **14**. The peripheral groove **64** is located in a lateral plane that is proximate to the end **24** of the base **12**, while the peripheral groove **66** is located in a lateral plane that is proximate to the end **22** of the base **12**. When the body **14** is seated within the base **12** (as shown in **FIG. 2**), the peripheral groove **64** and the inner surface **30** of the base wall **28** form a ring-shaped (i.e., annular) inlet chamber **68,** while the peripheral groove **66** and the inner surface **30** of the base wall **28** form a ring-shaped (i.e., annular) outlet chamber **70.** When the body **14** is seated within the base **12** (as shown by **FIG. 2**), the inlet chamber **68** aligns with the inlets **36, 38**, while the outlet chamber **70** aligns with the outlets **40, 42**, irrespective of the relative radial orientation of the body **14** within the base **12**. Alternatively, alignment means may be provided to allow the body **14** to be inserted into the base **12** to align the inlets **36, 38** with the inlet chamber **68** and to align the outlets **40, 42** with the outlet chamber **70.** The function of the inlet chamber **68** and the outlet chamber **70** shall be described hereinafter.

Still referring to **FIGS. 2** and **4a** through **4c,** the body **14** also includes a pair of diametrically opposed, cylindrical-shaped inlet passages **72, 74,** whose function will be described hereinafter. The inlet passages **72, 74** are aligned with the peripheral groove **64** and extend laterally therefrom to a centrally located, cylindrical-shaped body plug chamber **76,** whose function will be described hereinafter. The body **14** further includes a pair of diametrically opposed, cylindrical-shaped outlet passages **78, 80,** whose

function will be described hereinafter. The outlet passages **78, 80** are aligned with the peripheral groove **66** and extend laterally therefrom to a point that terminates within the body **14**. When the body **14** is fully seated within the base **12** (as shown in **FIG. 2**), the inlet passage **72** aligns with the inlet **36** and the inlet passage **74** aligns with the inlet **38** (not shown in **FIG. 2**). Similarly, when the body **14** is fully seated within the base **12** (as shown in **FIG. 2**), the outlet passage **78** aligns with the outlet **40** and the outlet passage **80** aligns with the outlet **42** (see **FIG. 2**).

Still referring to **FIGS. 2** and **4a** through **4c**, the body plug chamber **76** extends longitudinally from a bottom surface **82** of the body **14** to a point that terminates within the body **14**. The body plug chamber **76** includes internal threads **84** proximate to the bottom surface **82** of the body **14** (see **FIGS. 4b** and **4c**), the threads **84** performing a function which shall be described hereinafter. The body plug chamber **76** is directly connected to a centrally located, cylindrical-shaped stem spring chamber **86** that extends longitudinally within the body **14**. The function of the stem spring chamber **86** shall be described hereinafter. A longitudinally extending, centrally located, cylindrical-shaped orifice **88** connects the stem spring chamber **86** to a centrally located, cylindrical-shaped diaphragm chamber **90,** whose function shall be described hereinafter. An annular groove **92**, whose function shall be described hereinafter, lies within a top surface **94** of the body **14** and is spaced outwardly from a sidewall **96** of the diaphragm chamber **90**. A longitudinally extending, cylindrical-shaped passage **98** (see **FIG. 4b**) connects the diaphragm chamber **90** to the outlet passage **78,** which is, in turn, connected to a cylindrical-shaped safety chamber **100** by a connecting passage **102**. The safety chamber **100** extends longitudinally through the body **14** from the connecting

passage **102** to the bottom surface **82** of the body **14**. Similarly, the outlet passage **80** is connected to a cylindrical-shaped safety chamber **104** by a connecting passage **106**. The safety chamber **104** extends longitudinally though the body **14** from the connecting passage **106** to the bottom surface **82** of the body **14**. The safety chambers **100, 104** are specifically sized and shaped to house the safety components **20** of the regulator **10**. So as to facilitate the mounting the safety components **20** in a manner to be described in greater detail hereinafter, the safety chamber **100** is provided with internal threads **108** proximate to the bottom surface **82** of the body **14,** while the safety chamber **104** is provided with internal threads **110** proximate to the bottom surface **82** of the body **14**.

Still referring to **FIGS. 2** and **4a** through **4c**, the body **14** further includes three receiving slots **112, 114, 116**, each of which encircles the periphery of the body **14**. The receiving slot **112** is located between the end **62** of the body **14** and the peripheral groove **64.** The receiving slot **114** is located between the peripheral grooves **64, 66.** The receiving slot **116** is located between the peripheral groove **66** and the end **64** of the body **14.** O-rings **118, 120, 122** (see **FIG. 2**), whose function shall be described hereinafter, are mounted within receiving slots **112, 114, 116**, respectively. Alternatively, the O-rings **118, 120, 122** may be mounted to the inner surface **30** of the base wall **28.** The O-rings **118, 120, 122** are preferably manufactured from Parker Compound N674-70 rubber and are supplied by Parker Hannifin Corporation, but can be made from other materials and/or supplied from other manufacturers. The upper end **60** of the body **14** further includes external threads **124** (see **FIGS. 4b** and **4c**), whose function shall be described hereinafter.

Referring to **FIGS. 1** and **2**, the bonnet **16** includes an outer flange **126** and a hollow dome **128** that projects from the outer flange **126**. The outer flange **126** includes internal threads **130** (see **FIG.2**) that threadedly engage the external threads **124** of the body **14**, thereby enabling the bonnet **16** to be removably fastened to the body **14.** The dome **128** includes internal threads **132** and a centrally located bore **134,** whose functions shall be described hereinafter.

Referring to **FIGS. 2** and **5**, the pressure regulation components **18** include a diaphragm assembly **136** consisting of a convoluted diaphragm **138**, a diaphragm plate **140**, a diaphragm gasket **142**, a diaphragm post **144** and a relief spring **146**. The diaphragm **138** includes an outer periphery **148** on which is formed an annular sealing bead **150**, a single convolute **152,** a centrally located shallow recess **154** and a central opening **156**. The diaphragm **138** is positioned on the top surface **94** of the body **14** such that the annular sealing bead **150** of the diaphragm **138** is seated within the annular groove **92** of the body **14.** The diaphragm **138** is preferably made from nitrile/polyester, but it can be made of other materials.

Still referring to **FIGS. 2** and **5**, the diaphragm plate **140** includes a flange **158**, a raised central portion **160** and a central opening **162**. The diaphragm plate **140** is centrally positioned on top of the diaphragm **138,** whereby the flange **158** of the diaphragm plate **140** abuts against the convolute **152** of the diaphragm **138.** Preferably, the diaphragm plate **140** is manufactured from DELRIN® brand acetal rod by E.I. du Pont, but it may be manufactured from other brands of acetal rod or other materials. The diaphragm gasket **142** is fitted around the convolute **152** of the diaphragm **138** and against the top surface **94** of the body **14**, thereby sealing the diaphragm assembly **136**

to the diaphragm chamber **90.** The diaphragm gasket **142** is, preferably, manufactured from TEFLON® brand polytetraflouethylene (PTFE) by E.I. du Pont, but it can be made from other brands of PTFE or other materials.

Still referring to **FIGS. 2** and **5**, the diaphragm post **144**, which is preferably manufactured from ZAMAK 3 zinc alloy, but can be manufactured from other materials, includes a post base **164** having a circular lip **166**, a shaft **168** which extends longitudinally from the post base **164**, a flanged head **170,** a peripheral groove **172** located intermediate the shaft **168** and the flanged head **170**, and a central internally threaded cavity **174** located within the shaft **168**. The diaphragm post **144** is fitted within the central opening **156** of the diaphragm **138** and within the central opening **162** of the diaphragm plate **140,** whereby the post base **164** abuts against the diaphragm **138,** and the lip **166** of the diaphragm post **144** is positioned within the recess **154** of the diaphragm **138** and against the diaphragm plate **140**. Once assembled as shown in **FIG. 2**, the lip **166** of the diaphragm post **144** limits the axial movement of the diaphragm **138**, while the diaphragm post **144** promotes the centering of the diaphragm **138** and the diaphragm plate **140** in the body **14**. The relief spring **146** is fitted around the diaphragm post **144** such that one end **176** of the relief spring **146** abuts the raised central portion **160** of the diaphragm plate **140**, while an opposite end **178** of the relief spring **144** fits within the groove **172** and abuts against the flanged head **170** of the diaphragm post **144**. The relief spring **146** is preferably manufactured from zinc plated music wire, but it can be manufactured from other materials.

Still referring to **FIGS. 2** and **5**, the pressure regulation components **18** also include a stem **180**, a stem spring **182**, a disc-shaped, porous filter **184** and a body plug

186, whose functions shall be described hereinafter. The stem **180** includes a shaft **188,** an externally threaded head **190**, and a flanged stem seat **192** having a radially extending flange **194**. The externally threaded head **190** of the stem **180** threadedly engages the internally threaded cavity **174** of the diaphragm post **144**. When the stem **180** and the diaphragm post **144** are coupled, the shaft **188** of the stem **180** is positioned within the orifice **88** of the body **14** (see **FIG. 2**) and the stem seat **192** of the stem **180** is positioned within the stem spring chamber **86** of the body **14** (see **FIG. 2**). The stem spring **182** is located within the stem spring chamber **86** of the body **14** such that one end **196** of the stem spring **182** is fitted around the stem seat **192** and abuts the flange **194** of the stem **180**, while an opposite end **198** of the stem spring **182** abuts the filter **184**, which is positioned within the body plug chamber **76** of the body **14**. Preferably, the stem spring **182** is manufactured from zinc plated music wire, but it can be manufactured from other materials. The filter **184** is preferably disc-shaped, but it can consist of other shapes and sizes. In addition, the filter **184** is preferably manufactured from 10 micron sintered bronze 153, but can be manufactured from other materials.

Still referring to **FIGS. 2** and **5**, the body plug **186** includes a base **200,** a shaft **202**, an externally threaded flange **204** that extends radially from the shaft **202** and is located proximate to the base **200**, and an unthreaded flange **206** that extends radially from the shaft **202** and is located distal from the base **200**. The externally threaded flange **204** of the body plug **186** threadedly engages the internal threads **84** of the body plug chamber **76**, thereby allowing the body plug **186** to be removably fastened to the body plug chamber **76**. When the body plug **186** is fully inserted in the body plug

chamber **76** of the body **14**, the unthreaded flange **206** of the body plug **186** abuts the filter **184**. The shaft **202** of the body plug **186** has a centrally located cavity **208** that runs longitudinally through the shaft **202**. Two pairs of diametrically opposed holes **210, 212** extend laterally through the shaft **202** and communicate with the cavity **208**. Alternatively, the body plug **186** may contain less or more than the two pairs of diametrically opposed holes **210, 212**. When the body plug **186** is fully inserted in the body plug chamber **76** of the body **14** (as shown in **FIG. 2**), the holes **210, 212** of the body plug **186** align with the inlet chamber **68** of the body **14**, irrespective of the radial orientation of the body plug **186** within the body plug chamber **76**. The base **200** of the body plug **186** includes a plurality of notches **214** (not shown in **FIG. 5,** but see **FIG. 2**), which allow for the receipt of an assembly tool for fastening and unfastening the body plug **186** to and from the body plug chamber **76** of the body **14.** The body plug **186** is preferably manufactured from round bar brass 360 alloy, but it can be manufactured from other materials.

Still referring to **FIGS. 2** and **5**, the pressure regulation components **18** further include a main compression spring **216** and a setscrew **218**, which are fitted within the dome **128** of the bonnet **16.** The function of the main compression spring **216** and setscrew **218** shall be described hereinafter. The setscrew **218** includes a radially extending, externally threaded flange **220**, and a centrally located bore **222**. The externally threaded flange **220** of the setscrew **218** threadedly engages the internal threads **132** of the dome **128** of the bonnet **16**. The setscrew **218** is preferably manufactured from round bar brass 360 alloy, but can be manufactured from other materials. The main compression spring **216** extends longitudinally within the dome

128 of the bonnet **16** such that one end **224** of the main compression spring **216** abuts the flange **220** of the setscrew **218**, while an opposite end **226** of the main compression spring **216** abuts the diaphragm plate **140**, fitting within the flange **158** and around the raised central portion **160** of the diaphragm plate **140** as well as the shaft **168** of the diaphragm post **144** and the relief spring **146**. The main compression spring **216** is preferably manufactured from zinc plated music wire, but can be manufactured from other materials.

Referring to **FIGS. 2, 6a** and **6b**, the safety components **20** of the regulator **10** include a pair of safety seats **228, 230**, a pair of safety springs **232, 234** and a pair of safety caps **236, 238**, whose functions shall be described hereinafter. The safety seat **228** is positioned within the safety chamber **100** of the body **14,** while the safety seat **230** is positioned within the safety chamber **104** of the body **14**. The safety seat **228** includes a head **240**, which has two pairs of diametrically opposed arms **242** and a centrally located depression **244**, and a shaft **246**, which has a centrally located orifice **248** that extends longitudinally through the shaft **246** and communicates directly with the depression **244**. Similarly, the safety seat **230** includes a head **250**, which has two pairs of diametrically opposed arms **252** and a centrally located depression **254**, and a shaft **256**, which has a centrally located orifice **258** that extends longitudinally through the shaft **256** and communicates directly with the depression **254**. The arms **242, 252** of the safety seats **228, 230**, respectively, promote centering of the safety seats **228, 230** within the safety chambers **100, 104**, respectively. The first and second safety seats **228, 230** are, preferably, manufactured from DELRIN® brand acetal rod supplied

by E.I. du Pont, but they can be made from other brands of acetal rod or other materials.

Still referring to **FIGS. 2, 6a** and **6b**, the safety cap **236** includes a head **260**, an inner unthreaded shaft **262** that extends longitudinally from the head **260** and has a centrally located bore **264** that extends longitudinally through the inner shaft **262**, and an externally threaded, tubular outer shaft **266** that extends longitudinally from the head **260** and surrounds the inner shaft **262**. Similarly, the safety cap **238** includes a head **268**, an inner unthreaded shaft **270** that extends longitudinally from the head **268** and has a centrally located bore **272** that extends longitudinally through the inner shaft **270**, and an externally threaded, tubular outer shaft **274** that extends longitudinally from the head **268** and surrounds the inner shaft **270**. The externally threaded outer shaft **266** of the safety cap **236** threadedly engages the internal threads **108** of safety chamber **100**, while the externally threaded outer shaft **274** of the safety cap **238** threadedly engages the internal threads **110** of the safety chamber **104**, whereby the safety caps **236, 238** are removably fastened to and seal the safety chambers **100** and **104**, respectively. The safety caps **236, 238** are preferably manufactured from round bar brass 360 alloy, but they can be manufactured from other materials.

Still referring to **FIGS. 2, 6a** and **6b**, one end **276** of the safety spring **232** is fitted around the shaft **246** and abuts the head **240** of the safety seat **228**, while an opposite end **278** of the safety spring **232** is fitted within the shaft **274** such that it surrounds the inner shaft **262** and abuts the head **260** of the safety cap **236**. Similarly, one end **280** of the safety spring **234** is fitted around the shaft **256** and abuts the head **250** of the safety seat **230**, while an opposite end **282** of the safety spring **234** is fitted within the shaft

274 such that it surrounds the inner shaft **270** and abuts the head **268** of the safety cap **238**. The safety springs **232, 234** are preferably manufactured from spring steel wire SS 302, but they can be made of other materials.

Referring again to **FIG. 2**, the regulator **10** is assembled in the following manner. First, the pressure regulation components **18** and the safety components **20** are assembled and fitted within the body **14** and the bonnet **16** as previously described herein. Next, the bonnet **16** is fastened to the body **14**, whereby the internal threads **130** of the outer flange **126** of the bonnet **16** threadedly engages the external threads **124** of the body **14**, thereby enabling the bonnet **16** to be removably fastened to body **14.** The setscrew **218** serves as an adjustment for the main compression spring **216** within the dome **128** of the bonnet **16**. In this regard, the bore **134** in the dome **128** enables the receipt of a common tool, such as a hex wrench or screwdriver, to tighten or loosen the setscrew **218**, thereby adjusting a longitudinal force produced by the main compression spring **216** against the diaphragm **138** and diaphragm plate **140**, the effect of which shall be described hereinafter. The assembly consisting of the body **14,** the bonnet **16,** the pressure regulation components **18** and the safety components **20** is sometimes referred to herein as a "module."

Next, the so-called module is installed within the base **12** by a simple plug-like action. When the module is fully installed within the base **12,** the bottom surface **82** of the body **14** abuts the seat **34** of the base **12**, whereby the inlets **36, 38** of the base **12** align with the inlet passages **72, 74** of the body **14**, respectively (not shown in **FIG. 2**), while the outlets **40, 42** of the base **12** align with the outlet passages **78, 80** of the body **14**, respectively. This orientation allows the inlets **36, 38** and the outlets **40, 42** to

independently interface with the inlet passages **72, 74** and the outlet passages **78, 80**, respectively. In addition, when the module is fully installed within the base **12,** the O-rings **118, 120, 122** provide a gas-tight seal between the body **14** and the base **12** and between the inlet chamber **68** and the outlet chamber **70.**

Referring now to **FIG. 7,** the regulator **10,** as completely assembled, may be fastened to the mounting bracket **58** for mounting to a flat surface **284**, such as a wall. The mounting bracket **58** includes a circular-shaped aperture **286**, a pair of diametrically opposed regulator mounting holes **288, 290** and two pairs of diametrically opposed surface mounting holes **292.** When the regulator **10** is fastened to the bracket **58,** the aperture **286** of the mounting bracket **58** aligns with the aperture **26** of the base **12**, while the mounting holes **288, 290** of the mounting bracket **58** align with the mounting holes **54, 56** of the base **12**, respectively (not shown in **FIG. 7**). The aligned mounting hole **288** of the mounting bracket **58** and the mounting hole **54** of the base **12** receive one mounting screw **294,** while the aligned mounting hole **290** of the mounting bracket **58** and the mounting hole **56** of the base **12** receive another mounting screw **294**, thereby fastening the mounting bracket **58** to the bottom surface **52** of the base. Each of the surface mounting holes **292** of the mounting bracket **58** receives one of a plurality of surface mounting screws **296**, which fasten the mounting bracket **58** to the flat surface **284**. It is noteworthy that other fastening means are available to attach the mounting bracket **58** to the base **12** of the regulator **10** and/or the mounting bracket **58** to the flat surface **288.** While the mounting bracket **58** is preferably manufactured from 14 gauge stainless steel, it can be made from other materials.

Still referring to **FIG. 7**, an externally threaded inlet coupling **298** threadedly engages the inlet **36** (not shown in **FIG. 7**) of the base **12**, while an externally threaded outlet coupling **300** threadedly engages outlet **40** (not shown in **FIG. 7**) of the base **12.** Alternatively, the inlet coupling **298** can be threadedly engaged with the inlet **38** (not shown in **FIG. 7**) and/or the outlet coupling **300** can be threadedly engaged to the outlet **42** (not shown in **FIG. 7**) of the base **12.** An inlet hose **302** of the gas system is coupled to the inlet coupling **298** and preferably clamped by to the inlet coupling **298** by an inlet clamp **304**. Similarly, an outlet hose **306** of the gas system is coupled to the outlet coupling **300** and preferably clamped to the outlet coupling **300** by an outlet clamp **308**. In an alternative system, the inlet clamp **304** and/or the outlet clamp **308** need not be utilized. In addition, other clamping means are available to clamp the inlet hose **302** and the outlet hose **306** to the inlet coupling **298** and the outlet coupling **300**, respectively. An inlet gauge **310**, which measures and displays the pressure of the gas system flowing into the regulator **10**, is fastened to the inlet **38** (not shown in **FIG. 7**). Similarly, an outlet gauge **312**, which measures and displays the regulated output pressure of the gas exiting from the regulator **10**, is fastened to the outlet **42** (not shown in **FIG. 7**). It should, of course, be understood that the inlet gauge **310** would be fastened to the inlet **36** when the inlet **38** is coupled to the gas system. In a similar alternative, the outlet gauge **312** would be fastened to the outlet **40** when the outlet **42** is coupled to the gas system. Alternatively, the inlet gauge **310** and/or the outlet gauge **312** need not be utilized. In such cases, the inlet **36** or the inlet **38** (as the case may be) and/or the outlet **40** or the outlet **42** (as the case may be) are capped by means known in the art. It is noteworthy that while several of the aforesaid components, such as the

base **12**, body **14**, the aperture **26**, etc., are described as being preferably cylindrical in shape, each can consist of other shapes and sizes.

Referring to **FIGS. 2** and **7,** when the gas system is turned on, gas flows from the inlet hose **302** into the inlet **36** of the base **12** and into the inlet chamber **68** of the body **14**. The inlet gauge **310** connected to the inlet **38** measures and displays the input pressure of the gas flowing into the regulator **10**. Next, the gas flows through the inlet passages **72, 74** of the body **14,** through the diametrically opposed holes **210, 212** and into the cavity **208** of the body plug **186**, and through the filter **184**. The filter **184** prevents foreign matter from entering the stem spring chamber **86** and the orifice **88** of the body **14**, thereby preventing blockage thereof and/or damage to the stem **180**, which could result in misadjustment of or damage to the regulator **10.** The gas then flows through the stem spring chamber **86** and the orifice **88**, whereby the diameter of the shaft **188** of the stem **180** regulates the flow of the gas. In this regard, the larger the diameter of the shaft **188** of the stem **180**, the lesser the flow rate of the gas through the regulator **10**. Conversely, the smaller the diameter of the shaft **188** of the stem **180**, the greater the flow rate of the gas through the regulator **10**.

Next, the gas enters the diaphragm chamber **90** of the body **14**, whereby the gas pressure created therein causes the diaphragm **138** to expand. The convolute **152** of the diaphragm **138** reduces stretching thereof (which can lead to tearing or rupturing of the diaphragm **138**) when the gas pressure is present. When the diaphragm **138** expands, it forces the diaphragm plate **140** to travel longitudinally along the shaft **168** of the diaphragm post **144** in a direction away from the post base **164**. The relief spring **146** creates a counteracting longitudinal force against the raised central portion **160** of

the diaphragm plate **140,** thereby limiting the travel of the diaphragm plate **140** along the shaft **168** of the diaphragm post **144**. In addition, a counteracting longitudinal force produced by the main compression spring **216** against the diaphragm assembly **136** offsets the gas pressure, thereby limiting the distance that the diaphragm **138** can expand. When the gas pressure within the diaphragm chamber **90** decreases, the diaphragm **138** contracts and the relief spring **146** forces the diaphragm plate **140** to travel along the shaft **168** of the diaphragm post **144** towards the post base **164**. As the diaphragm **138** cycles between expansion and contraction, the stem **180** modulates via the stem spring **182**, continuously valving the gas through the regulator **10** and, accordingly, controlling the output pressure of the gas. The gas then travels out of the diaphragm chamber **90** through the passage **98** and into the outlet passage **78,** through the outlet chamber **70** and out of the regulator **10** through outlet **40,** and finally into and through the outlet hose **306** of the gas system. The outlet gauge **312** measures and displays the outlet pressure of the gas flowing out of the regulator **10.**

In the event of the existence of any back pressure within the diaphragm chamber **90**, or if a sufficient amount of debris is caught between the stem seat **192** of the stem **180** and/or orifice **88** (whereby a vacuum is created within the diaphragm chamber **90**), the diaphragm **138** will burst and the gas will be relieved. In the event that excessive overpressure of gas occurs within the regulator **10**, the safety components **20** provide relief therefor. In this manner, the overpressure of gas is released through the connecting passages **102, 106** and the depressions **244, 254** and orifices **248, 258** of the safety seats **228, 230,** thereby causing the safety seats **228, 230** to travel longitudinally within the safety chambers **100, 104**, respectively, towards the end **62** of

the body **14**. The safety springs **232, 234** ensure that the correct amount of pressure is relieved such that they limit the travel of the safety seats **228, 230** within the safety chambers **100, 104**, respectively. The overpressure of gas then exits out of the bores **264, 272** of the heads **260, 268** of the safety caps **236, 238**. The cavities **44, 46, 48, 50** of the base **12** allow for the disbursement of the overpressure of gas from the regulator **10**, especially when the aperture **26** of the base **12** is impeded by the flat surface **284** to which the regulator **10** is mounted. By providing for the release of a substantial overpressure of gas in the foregoing manner, the safety components **20** prevent or reduce damage to the various components of the regulator **10** and to the gas system to which the regulator **10** is attached.

If maintenance or replacement of the regulator **10** is required, the module (i.e. the assembly consisting of the body **14**, the bonnet **16**, the pressure regulation components **18** and the safety components **20**) may easily be removed from and installed in the base **12** without physical uncoupling the base **12** from the inlet hose **302** and the outlet hose **306** of the gas system. The pressure regulation components **18** and/or the safety components **20** may be readily replaced or disassembled for maintenance by removing the bonnet **16** from the body **14.** For instance, if the filter **184,** stem spring **182** and/or stem **180** need replacing, only the body plug **186** need be removed. Similarly, if one the safety seats **228, 230** and/or the safety springs **232, 234** needs replacement, then only the corresponding safety caps **236, 238** need be removed. Finally, if any component of the diaphragm assembly **136** and/or the main compression spring **216** needs replacement, then only the bonnet **16** need be removed. This eliminates the need to substantially disassemble the regulator components when replacing any of the

aforesaid components. Consequently, this reduces both time and labor costs when maintenance or replacement of the regulator **10** is carried out.

It should be understood that the embodiment described herein is merely exemplary and that a person skilled in the art may make many variations and modifications without departing from the spirit and scope of the present invention. Accordingly, all such variations and modifications are intended to be included within the scope of the invention as defined in the appended claims.